4-1986

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Disciplines
Agribusiness | Economic Policy | Growth and Development | Other Public Affairs, Public Policy and Public Administration

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Staff Paper Series No. 156

Department of Economics
Iowa State University
Ames, Iowa

April 1986

2-18-85
7-12-85
4-17-86

IMPROVEMENT OF WHEAT VARIETIES IN THE U.S., 1919-1979

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Introduction

This paper examines the development and adoption of Hard Red Winter (HRW), Hard Red Spring (HRS), and Soft Red Winter (SRW) wheat varieties in the major wheat producing states in the U.S. from 1919-1979. Both methods of varietal improvement and sources of new varieties have changed over the last 100 years. The purpose of this study is to analyze changes in the institution of origin, the geographical origin, and the varietal composition of wheat acreage in an attempt to better understand the development and adoption of new wheat varieties over the 60 years.

Much of the data used in this study were collected from a series of USDA publications published at 5-year intervals since 1919. The USDA reports wheat varieties, acreage harvested of each variety, and the percentage of total wheat acreage occupied by each variety in each state. From 1919 to 1969, all varieties of wheat covering more than 0.1% of each state's total wheat acreage were reported; after 1974, varieties occupying more than .01% were reported. Also, the USDA has periodically compiled data on plant breeding and pedigree information on wheat varieties.

This paper is divided into four sections: the development of improved varieties; plant breeding sources by state of origin; varietal composition of harvested acreage; and the institutional type (i.e., public, private, imports) breeding sources by institution. The first section focuses on the development of improved varieties, and it contains an overview of wheat development before the 1920s. Methods of varietal improvement as well as pioneers in wheat

*The authors are research assistant and professor of economics, respectively, Department of Economics, Iowa State University. Financial assistance for this study was received from the USDA-CSRS through a grant to Yale University, 1980-81 and a cooperative agreement to Iowa State University, 1984-86, and from the Iowa Agriculture and Home Economics Experiment Station, project 2516.

development are discussed. The early role of the agricultural experiment stations is also considered. The second section identifies the plant breeding source of each variety by state, with the percentage of harvested wheat acreage classified as originating in the local or home state, neighboring states, other states, or foreign imports. Varietal composition of acreage is discussed in the third section. This is a summary of the number of varieties grown, the mean share, variance of the share and the dominant wheat variety harvested for each state and year. The fourth section identifies plant breeding source by institution of origin. The institutional origins are categorized as U.S. public, U.S. private, foreign, and unknown. Public sources include agricultural experiment stations, federal government and other public agencies. Foreign imports consist of all varieties developed abroad, regardless of whether they were developed by private or government sources.

DEVELOPMENT OF IMPROVED WHEAT VARIETIES

Rather large increases in average wheat yields have been achieved in the United States over the past 60 years. In 1919, winter and spring wheat yields averaged 14.8 and 9.0 bushels per acre, respectively. Sixty years later, winter wheat yields had increased to 36.9 bushels per acre and spring wheat yields had more than tripled to 28.2 bushels per acre.[1/] Part of this increase can be attributed to genetic improvement of wheat varieties. In addition to improved yields, varieties have been developed to withstand adverse conditions of nature e.g., rusts, drought. This aspect of wheat breeding continually faces new challenges, as diseases and insects and other pests arise to which

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1/ USDA Agricultural Statistics.

established varieties are not immune. Wheat varieties have gradually changed over time. The following section discusses how improvements in wheat varieties were achieved, including breeding methods and the role of public and private sources.

Wheat is not native to the United States. Even though it was first planted by settlers in the 1600s, the English and French varieties introduced at that time did not become permanent. Corn was native to North America, and it was better suited to the East Coast climate. Wheat became more popular in the 18th Century as French immigrants planted it in Illinois (Ball, 1930). Spanish wheats were introduced to California via Mexico, e.g., Sonora is believed to have been grown in California as early as 1770.

The demand for wheat expanded in the 1800s as the size of the U.S. population grew rapidly and real incomes increased as better milling processes were developed. At this time, the only means of improving wheat varieties was the introduction of imports. Many varieties came from Europe, although some varieties were also imported from Asia. Selections were made from mixtures, mutants, and natural hybrids.

A controversy of the early 1800s illustrates the problems of wheat producers and consumers of that era and showed the need for improved wheat varieties and milling technology. Mediterranean, a semi-hard red winter wheat, was very popular with farmers in the mid-1800s because of its resistance to the Hessian fly. It, however, had major milling problems. When Mediterranean was milled, its red kernels discolored the flour. White wheats did not have this problem and they were standard. Millers also objected to Mediterranean because of the difficulty of removing the bran of hard wheats. It was widely grown in spite of the criticisms, and eventually better milling processes made it more acceptable. Mediterranean was grown on over 250,000 acres as late as

1949 (Ball, 1930).

The need to improve wheat stemmed from a number of reasons. The end of the Civil War released large amounts of labor and much land remained to be settled in the Midwest and west; production was becoming more mechanized as reapers, binders, and threshers were developed. Better milling procedures also enhanced quality of wheat flour.

The Morrill Act (1862) and Hatch Act (1887) established new educational and research institutions that would become a major force in applying scientific principles to wheat varietal development and testing. These acts established the land-grant colleges and the agricultural experiment stations. The early role of the agricultural experiment stations did not involve plant breeding. It was primarily focused upon testing existing varieties to determine which ones were best for their climate and soil conditions. Frequently, the agricultural experiment station tested varieties that were already grown in other states and abroad as well as locally grown varieties. These tests were focused on comparing varietal characteristics such as yield, disease resistance, and grain quality. In addition to testing varieties, the experiment stations recommended and sold varieties that they found to be well suited to their state.

In some cases, the experiment station had a great deal of influence. For example, in 1900, the researchers at the Nebraska Ag Experiment Station concluded that "If the proper winter wheat can be found, Nebraska will be among the great wheat producing states of the Union." That year, hardy strains of winter wheats were sent to 400 farmers in northern and southwestern Nebraska for testing. In the five years that followed, the production of winter wheat in Nebraska increased by 10 million bushels per year. The researchers felt that the increased production was largely due to the results of the

experiments. The results were especially striking for northwestern Nebraska, where production increased from almost nothing in 1900 to over 9 million bushels harvested only six years later.

Although most of the wheat producing states were testing varieties and experimenting with fertilizer response, seeding methods and other cultural practices at about the same time, entry into wheat breeding itself varied by as much as 20 years. Furthermore, private production of hybrid wheats began over 20 years before to the entrance of any agricultural experiment stations into that endeavor. Many of the states used selection, or the choosing of the best plants for propagation; hybridization was pursued more rigorously and at an earlier date in only a few states.

Before scientific experimentation, field selections were common and were made on the basis of performance characteristics such as yield or resistance to disease, lodging or pests. Usually no special attempt was made to produce a new variety of wheat. For example, the variety of SRW wheat called Leap originated from one plant in J. S. Leap's field in Virginia in 1901. It was in general distribution by 1907 and later became very popular. Another variety, White Winter, may have originated from the natural cross of several varieties planted in one field. In fact, many of the chosen plants were thought to be natural hybrids. This may be due to the practice by some farmers of mixing varieties within a field to increase yield.

Some of the varieties obtained by selection were very successful. An example of such a variety is Red Fife. This variety, originally from Poland, was taken from Germany to Scotland. It was imported into Canada by David Fife of Ontario, who saved a single plant of spring wheat out of a lot of winter wheat and began the production of Red Fife. It proved to be very popular in Wisconsin and became the basis for the Minneapolis milling industry. Red Fife

was a parent of Marquis, which was at one time the leading hard red spring wheat in the United States (Clark, 1936).

As the examples illustrate, the private sector played an important role earlier than did the experiment stations in developing new varieties through selection. However, the ag experiment stations produced some excellent results via selection, one such variety being Kanred, a pure line selection developed by the Kansas Ag Experiment Station in 1918.

By 1900, hybridization was recognized as having great potential to improve wheat. The production of commercial varieties resulting from hybridization began around 1870. It usually was carried out by plant breeding farmers that specialized in this work. One such farmer, A. N. Jones of New York, produced 15 varieties from hybrids and was among the first to practice composite crossing. Other pioneers in this endeavor included C. G. Pringle of Vermont and A. E. Blount of the Colorado Ag College. Much of the early crossing involved closely allied varieties rather than vastly different crosses (Clark, 1936).

The rediscovery of Mendel's laws facilitated progress in wheat breeding in the 20th Century. Professor Spillman of the Washington Ag Experiment Station made one of the earliest discoveries of the principles of heredity in plant breeding, resulting in the development of a number of hybrid varieties (Bayles & Clark, 1954).

From the turn of the century into the 1920s, the role of many agricultural experiment stations continued to be that of determining the best varieties for their state, rather than developing new varieties. There are, however, a few notable exceptions. Nebraska, Minnesota, North Dakota, Washington and Colorado all began experiments with hybrids around 1900. A Minnesota agronomist wrote in 1899 that "In 1892, many of the strongest plants in the field crop nursery

were artificially cross-pollinated." Nebraska had crossed 6 varieties by 1892, and North Dakota had obtained good crosses by 1897. Twenty years later, Indiana, Missouri and Ohio also obtained good results through hybridization.

From the 1920s through the 1940s, the role of ag experiment stations in wheat varietal development increased, especially in the major wheat producing states. Many varieties were also imported from Canada at this time. Some varieties were still selected from farmers' fields. For example, Stafford was selected as the only surviving plant in a Kansas field badly damaged by rust. Requa was a natural cross found in a farmer's field in Washington and was released for distribution in 1931.

In the 1950s and 1960s, private breeders and ag experiment stations, often in conjunction with the Crops Research Division of the USDA, continued to play an important role in the development of new wheat varieties. Varieties continued to be imported from Canada. Many of the varieties released for distribution in the 1970s were the result of scientific work at ag experiment stations, universities, private companies, and the Agricultural Research Service.

Today, the development of new varieties involves scientific methods to meet specific needs of wheat producers, e.g., improved yields, resistance to pests and diseases. Sixty years ago the development process was quite different. New varieties were often discovered by chance, and principles of plant breeding were just being established. The ag experiment stations have played a major role in developing improved varieties of wheat.

PLANT BREEDING SOURCES OF WHEAT VARIETIES IN THE U.S., 1919-1979 BY GEOGRAPHICAL ORIGIN

Hard Red Winter Wheat

The source of HRW wheat varieties harvested in the U.S. has changed significantly over the last 60 years. This section examines the origin of varieties harvested in the major producing states of Kansas, Oklahoma, Texas, Colorado, Nebraska and Montana, as well as the minor producing states, which are considered by region. Table 1 summarizes the origin of varieties harvested in the major HRW wheat producing states. In the early years of this century, imported varieties were planted, then new varieties were developed in the states that would out-perform imports. These were developed by private and public sources.

Kansas Kansas is the major producer of HRW wheat in the U.S. Although some soft red winter wheat was grown in Kansas in the early part of this century, HRW has been produced almost exclusively since the 1950s. Imported varieties comprised 99 percent of the HRW wheat harvested in 1919. Their use gradually decreased and died out by 1959. They were displaced by varieties originating from Kansas and other neighboring states. The harvesting of varieties developed in Kansas peaked in 1944, when 83.2 percent of the harvested varieties had local origins. Use of these varieties diminished as varieties from Nebraska, and to a lesser extent from Oklahoma, were introduced. Recently, varieties from Texas have gained a share of the acreage.

Oklahoma Oklahoma is the second most important producer of HRW wheat in the United States, and like Kansas, now grows almost no other type of wheat. The use of imported varieties in Oklahoma declined after 1919, as varieties originating in neighboring states supplanted them. Kansas was the main source

of new varieties until 1954, when varieties developed in Nebraska and Texas came into greater use. In 1979, 40 percent of the wheat varieties harvested in Oklahoma were developed in Texas. The use of locally developed varieties peaked in 1959 at 69.6 percent of the acreage harvested.

Texas Production of soft red winter wheat in Texas has been superseded over the last 60 years by HRW wheat. By 1979, 85 percent of Texan wheat was HRW. Although locally developed varieties are now most prevalent, none was harvested in significant quantities until 1949. The early imports were replaced by varieties originating in other states. In the 1920s, Indiana varieties were popular, only to be replaced by Kansas developed wheat. The harvesting of Kansas developed varieties peaked in 1954 and declined as varieties developed in Oklahoma and Texas became dominant. The harvesting of Texas developed varieties has increased in recent years.

Colorado Another major producer of HRW, Colorado, did not plant significant quantities of locally developed varieties until 1974. By 1979, 22.8 percent of the wheat acreage was planted to Colorado developed varieties. The foreign imports of the early 20th Century were replaced by varieties developed in Kansas, which in turn were supplanted by Nebraska developed wheats. Nebraska developed varieties constituted 77.2 percent of the acreage in 1974; their use abated as Colorado developed varieties gained importance.

Nebraska Like Kansas, Nebraska relied to a large degree on locally developed varieties by the 1940s. Their use peaked in 1974 at 97.7 percent of the harvested acreage and remains high. The foreign imports that were used exclusively in 1919 were initially replaced by varieties developed in Kansas and later by varieties developed in Nebraska. A small share of the acreage continues to be planted to imported varieties.

Montana Wheat acreage in Montana is divided between HRW and HRS. HRW

wheat production peaked in 1969 with 64.4 percent of the wheat acreage, decreasing to 47.2 percent in 1979. Unlike the other major producers of HRW, imported varieties are still significant in Montana. The early imported varieties were from Europe, and their use declined to 1.9 percent of the harvested acreage in 1964. Canadian developed varieties became important in the 1960s, when 46 percent of the acreage was planted to foreign developed varieties. Imported varieties accounted for 25.5 percent of the acreage in 1979. The planting of locally developed varieties expanded to over one-half of the acreage in 1954, but it has declined to 10 percent or less since 1964. Kansas varieties were harvested widely until 1959, before wheat varieties developed in Nebraska became popular.

Upon examining the origin of varieties harvested in the major HRW wheat producing states, a pattern becomes clear. Varieties of wheat developed in Kansas replaced the foreign (European) imports of the early 20th Century; by the 1950s, Nebraska developed varieties came into widespread use. The 1970s show a trend toward harvesting Oklahoma and Texas developed wheats.

HRW wheat is also grown, to a lesser extent, in the Corn Belt (Illinois, Indiana, Iowa, Missouri, Ohio); the Lake states (Michigan, Minnesota, Wisconsin); the Northern Plains (North Dakota, South Dakota); the Eastern states (New York, Pennsylvania); Appalachian regions (Kentucky, Tennessee, West Virginia); the Western states (Idaho, New Mexico, Utah, Wyoming): and the Pacific states (California, Oregon, Washington). These states will be analyzed by region.

The Corn Belt With the exception of Indiana, mostly imported varieties were grown in these states through 1929. Indiana farmers were harvesting locally developed varieties heavily from the late 1920s into the 1940s. Ohio and, to a lesser degree, Illinois farmers moved into planting Indiana

developed varieties at that time. Locally developed varieties took precedence in Iowa by 1939. By 1949, however, varieties developed in Kansas and Nebraska became, and continue to be, the most widely harvested wheats in all of these states, with the exception of the prevalence of Oklahoma developed varieties in Missouri beginning in 1959.

Lake States These states display a somewhat different pattern of variety adoption. In Minnesota and Wisconsin, foreign imports were replaced by locally developed varieties. Minnesota used its own varieties exclusively in the 1950s and 1960s, after which varieties developed in the Dakotas became significant. Wisconsin farmers shifted from varieties developed in their state to Minnesota developed varieties in the 1940s and to Nebraska developed varieties almost completely in the 1950s and 1960s. In the 1970s, Minnesota developed varieties again became prominent in Wisconsin. Production of HRW wheat became insignificant in Michigan by 1969.

Northern Plains Imported varieties were harvested extensively in the Dakotas through 1949, when Nebraska developed varieties replaced them. North Dakota farmers began harvesting significant quantities of locally developed varieties in the 1970s, and by 1979, varieties developed in North Dakota constituted a majority of the harvested acreage.

Eastern States Production of HRW wheat has been erratic here. Little was produced before 1939 or after 1959. Illinois developed varieties were harvested extensively in the 1940s, but they were replaced by Kansas and Nebraska developed varieties in the 1950s.

Appalachian Regions Foreign imports predominated in this region as late as 1949. Oklahoma developed varieties were very popular by 1959 in Kentucky and Tennessee, and have been harvested almost exclusively there for the last 20 years. West Virginia acreage has been split between Kansas and Nebraska

developed varieties.

Pacific States Imported varieties dominated in Oregon as late as 1959, when harvesting of locally developed varieties expanded. By 1979, Oregon farmers had adopted Washington developed wheats. Washington farmers also depended on imported varieties until 1949 while minor use fluctuated between locally and Oregon developed varieties. By 1969, locally developed varieties took precedence in Washington. California, which relied heavily on foreign varieties, had essentially ceased production of HRW wheat by 1959.

Western States With the exception of Utah, foreign wheat varieties were also prevalent in this region into the 1940s. Utah farmers were harvesting primarily varieties developed in Utah, and they continue to harvest locally developed varieties. Utah varieties also gained a foothold in Idaho which persisted through 1969. Idaho farmers then shifted to locally developed varieties. New Mexico and Wyoming farmers harvested Kansas varieties extensively until the 1950s, when the use of Nebraska developed varieties expanded. Nebraska developed wheat varieties continue to dominate harvested acreage there.

Summary

Foreign and local or regional varieties were the general rule in HRW wheat production from 1919 through 1939. In 1949, the mix was modified as varieties developed in Kansas and Nebraska were widely adopted in all states except the western and Pacific states and Minnesota. Although varieties developed in Kansas and Nebraska remain popular in most of these states, by 1979, varieties developed in Oklahoma became prevalent in the south and Appalachian regions while the use of regional varieties expanded in the north and west.

Hard Red Spring Wheat

Most of the U.S. hard red spring wheat is produced in the northern states of Minnesota, Montana, South Dakota and North Dakota. Table 2 summarizes the origin of varieties grown in these states. The harsh winters of these states makes the production of spring wheat more feasible than winter wheat, despite the relatively lower yield of spring wheat. Because winter wheat is sown in the fall, it generally does not survive the cold winter temperatures of this region (Reitz, 1976).

Sixty years ago, imported varieties of hard red spring wheat were harvested. They were gradually replaced by varieties developed in these northern states, except for a reemergence of foreign varieties in the 1950s.* Most of the HRW wheat varieties harvested today were developed in North Dakota and Minnesota. A few states, especially those with milder climates, have ceased production of hard red spring wheat in the last 20 years.

North Dakota North Dakota is the largest producer of hard red spring wheat in the United States. About 60 percent of North Dakota's harvested wheat acreage is seeded to varieties of hard red spring wheat. Foreign varieties were planted and harvested in North Dakota until the 1930s. By 1939, 61 percent of the harvested acreage was planted to varieties developed in Minnesota, and 30 percent to locally developed varieties. These proportions switched within 10 years. In 1959, imported (Canadian) varieties were again dominant. Following the shift to foreign varieties, varieties developed in Minnesota and North Dakota again became popular, with 82 percent of the

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* These Canadian varieties were resistant to a new virulent form of stem rust ("race 15B"), which had become prevalent and threatened the previously used wheat varieties (Peterson, 1965).

harvested acreage planted to North Dakota developed varieties in 1979.

Montana Montana is the second largest producer of hard red spring wheat. Foreign varieties were prevalent there until 1949, when varieties developed in Minnesota and North Dakota were widely adopted. By 1979, varieties developed in North Dakota became prevalent, and smaller acreages were harvested of varieties originating in Minnesota and Montana.

Minnesota Minnesota harvests mostly hard red spring wheat. Foreign varieties were harvested through 1959, with the exception of the late 1940s, when 75 percent of the wheat acreage consisted of varieties developed in North Dakota. By 1969, locally developed varieties were dominant in Minnesota.

South Dakota The transition from foreign varieties to those developed in North Dakota and Minnesota occurred during the 1930s. Ninety percent of the wheat acreage was planted to varieties developed in North Dakota by 1949. In the 1950s, foreign varieties and varieties developed in Minnesota were widely harvested. By 1979, North Dakota developed varieties, along with some originating in Minnesota and California, constituted a majority of the acreage.

Hard red spring wheat is also produced in the Midwest (Illinois, Iowa, Wisconsin), the Plains (Nebraska, Texas), the West (Colorado, Idaho, New Mexico, Utah, Wyoming), and the Pacific (California, Oregon, Washington). The more southern states of Illinois, Iowa, Nebraska, New Mexico and Texas grew little or no hard red spring wheat after the 1940s.

Pacific Foreign varieties of hard red spring wheat were grown in Washington until after 1949. Since then, varieties developed in North Dakota have been most widely harvested, along with some originating in Wisconsin and Minnesota. California ceased production of hard red spring wheat from the 1930s until the 1950s. Imported varieties were grown there until 1979 when

locally developed varieties comprised a majority of the crop. Oregon harvested mostly foreign varieties until after 1959. At that time, use of locally developed varieties expanded. By 1979, 64 percent of the wheat acreage was planted to varieties developed in California.

Western States Colorado harvested foreign varieties until the late 1930s, when varieties developed in North Dakota, and later Minnesota, came into use. Minnesota developed varieties became the most widely harvested by 1969. In 1979, Colorado harvested varieties developed in North Dakota, along with locally developed and imported varieties.

Idaho depended on imported varieties until the late 1940s, when varieties originating in North Dakota comprised a majority of the harvested acreage. Idaho continued its reliance on North Dakota developed varieties until the late 1970s. Minnesota and locally developed varieties were recently adopted.

Foreign varieties were grown in New Mexico until 1949 when varieties developed in Minnesota became popular. New Mexico did not produce hard red spring wheat after 1969.

Utah relied exclusively on foreign varieties until the 1950s, shifting quickly to varieties developed in North Dakota. Varieties developed in North Dakota are still predominant, with lesser acreage planted to varieties developed in Minnesota in the 1960s and varieties developed in Utah and Idaho in the 1970s.

Wyoming harvested mostly foreign varieties until the late 1940s, when planting of varieties developed in North Dakota increased. A large share of the acreage is still planted to varieties developed in North Dakota, although over half of the harvested acreage is now planted to varieties developed in Minnesota.

Plains States Texas harvested foreign varieties exclusively until production of hard red spring wheat ceased in the 1930s. Small acreages of locally developed varieties were harvested in the 1940s. Production was discontinued again in the 1950s. Foreign varieties became prevalent as production resumed.

Nebraska relied on foreign varieties until the 1930s when varieties developed in North Dakota, and to a lesser extent from Minnesota, became prevalent. By 1959, only varieties originating in North Dakota were harvested. Nebraska ceased production of hard red spring wheat after the 1960s.

Midwest States Foreign varieties and small acreages of varieties developed in Minnesota were harvested in Iowa through the 1920s. Varieties originating in Minnesota were dominant by 1939. They were replaced by varieties developed in North Dakota and Wisconsin in the 1940s, and by foreign varieties in the 1950s. Varieties from Minnesota made a comeback, consisting of half of the harvested acreage in 1969. By 1979, Iowa had ceased production of HRS wheat.

Illinois farmers harvested foreign varieties until 1939, when they shifted to varieties developed in Wisconsin. By 1949, varieties developed in Wisconsin were harvested exclusively. In the 1950s, only foreign varieties were produced exclusively. Production ceased during the 1960s.

The foreign varieties of sixty years ago were gradually supplanted by locally developed varieties in Wisconsin. Wisconsin farmers harvested varieties developed in their own state exclusively by 1949. Some foreign varieties were added in the 1950s, although home state varieties remained dominant. Use of foreign varieties expanded during the 1960s. In 1979, 73 percent of harvested acres were planted to varieties developed in Minnesota, and 17 percent to varieties developed in North Dakota.

Summary

Most of the production of HRS wheat occurs in the northern states. Some of the states further south produced HRS wheat at one time but have since ceased production. Mostly foreign varieties were planted and harvested sixty years ago, then a shift occurred to varieties developed in North Dakota and Minnesota in the 1930s and 1940s. Exceptions are Wisconsin and Illinois, which harvested varieties developed in Wisconsin; Texas, which harvested locally developed varieties; and Oregon and Utah, which stayed with foreign varieties. There was a resurgence of foreign varieties in most of the HRS wheat producing states in the 1950s. By the 1970s, varieties developed in North Dakota and Minnesota were dominant in all of these states except California, Idaho and Texas. California and Idaho harvested locally developed varieties, and Texas harvested foreign developed varieties.

Soft Red Winter Wheat

The major soft red winter wheat producing states are located in the Corn Belt and eastern United States. Most of the early American varieties were developed in the eastern states, but varieties developed in Ohio and Indiana are relatively important in recent years. Table 3 contains a summary of the origin of varieties in the major producing states of Missouri, Ohio, Illinois, and Indiana.

Missouri Missouri is the major producer of SRW wheat in the United States. Acreage of SRW wheat exceeded 1 million acres from 1919-1949, then it declined to 550,000 acres in 1959. SRW acreage exceeded 1 million acres in 1974 and 1979. Foreign varieties and varieties developed in Pennsylvania dominated the SRW wheat acreage in Missouri from 1919 to 1939. By 1939, varieties developed in Kansas gained a foothold, increasing to 77 percent of

harvested wheat acreage in 1949. A decade later, varieties developed in Idaho and Indiana became important, with those from Indiana taking precedence in 1979.

Ohio Ohio is the second major producer of SRW wheat, producing almost no other type of wheat after 1924. The early imported varieties were replaced by varieties developed in Ohio. Ohio developed varieties comprised 86 percent of total wheat acreage from 1939-1949, but they became less important when farmers adopted varieties developed in Indiana. In 1979, 57 percent of harvested acreage was planted to Indiana developed varieties, and 39 percent to varieties developed in Ohio.

Illinois In the early 20th Century, Illinois farmers harvested SRW wheat varieties that were developed in Pennsylvania and New York and abroad. The imported varieties were replaced by varieties developed in Ohio. The wheats harvested in Illinois in 1949 were developed in many different states. From this mix, varieties developed in Indiana increased in importance, comprising 97 percent of total wheat acreage in 1979.

Indiana Like Ohio, Indiana produces almost no other type of wheat than SRW. From 1919 to 1939, varieties developed in New York, Pennsylvania, and Ohio and abroad comprised the bulk of harvested acres. By 1949, mostly locally developed varieties were planted, along with varieties developed in Ohio. By 1979, Indiana varieties were the most widely harvested.

Texas In 1919, 59.4 percent of Texas wheat acreage was SRW. Its significance has decreased over time, falling to 6.4 percent in 1979. Foreign varieties were widely planted from 1919-1939. Varieties developed in Texas covered one-half of the harvested acreage in 1949, but were soon supplanted by varieties that had been developed in Idaho and Missouri. In 1979, most of the harvested acreage was planted to varieties developed in South Carolina.

Kentucky and Tennessee The pattern of adoption is very similar in these states. Early in the 20th Century, varieties developed in New York, Pennsylvania, Virginia, and abroad constituted the majority of harvested acreage. In 1949, varieties developed in Ohio were widely used along with varieties from South Carolina, Kansas, and Pennsylvania. By 1959, Idaho and Indiana were the main sources of new varieties; those developed in Indiana gained significantly, increasing to 94 percent of harvested acreage by 1979.

Pennsylvania The foreign varieties of the 1920s were replaced by varieties developed in Virginia. Varieties developed in New York and Pennsylvania were also harvested at that time. For a time, varieties developed in Ohio comprised a large share of the SRW wheat acreage, but they decreased in importance as varieties developed in Pennsylvania and Indiana were adopted. Varieties developed in Indiana were the most widely harvested in 1979.

North Carolina The sources of varieties harvested in North Carolina were similar to those of Pennsylvania until 1949, when varieties developed in South Carolina became the most popular. Varieties developed in North Carolina and Virginia were widely used from 1959 to 1969. They were replaced by varieties originating in Indiana.

Virginia In the early 1900s, most of the harvested acreage was planted to varieties developed in Virginia and New York. By 1959, Ohio had become an important source of wheat varieties harvested in Virginia. Later the Ohio developed varieties were replaced by varieties originating from North Carolina. In 1979, Indiana was the major source of SRW wheat varieties harvested in Virginia.

Minor producers of SRW wheat include: the Lake States (Michigan, Minnesota, Wisconsin); Eastern States (Maryland, New York, South Carolina, West Virginia); Plains States (Kansas, Nebraska, Oklahoma): Western States (Idaho,

Montana, New Mexico, Utah, Wyoming) and Iowa and Washington. Production in these states has been highly variable, with a number of them ceasing production by 1950.

Lake States These states do not share similar patterns of variety adoption. Minnesota harvested foreign developed varieties from 1919 to 1939, shifting to varieties developed in Wisconsin by 1949. No SRW wheat was produced in Minnesota in 1969; the 1979 acreage consists of varieties developed in other states. Michigan farmers harvested locally developed varieties and some New York and foreign varieties until the 1940s, when varieties developed in Ohio became important. Use of varieties developed in Indiana began around 1949, and expanded to become the most widely harvested varieties in the 1960s and 1970s. Wisconsin planted mostly foreign varieties of SRW wheat, along with varieties developed in Pennsylvania, in the early 1900s. Production had ceased by 1939. As production of SRW wheat resumed in Wisconsin in the 1940s and 1950s, locally developed varieties were planted. Home-state developed varieties are still dominant in Wisconsin.

Eastern States SRW wheat is the major type of wheat grown in Maryland and South Carolina. New York harvests almost no SRW wheat today. West Virginia did not begin producing SRW winter wheat until the late 1950s. New York farmers planted mostly locally developed varieties until 1959, then shifted to varieties developed in Pennsylvania, Indiana, and other states. South Carolina also relied heavily on locally developed varieties for a time. The use of foreign varieties then diminished and locally developed varieties became more popular. By 1959, varieties developed in Virginia were the most frequently harvested, then they were replaced by varieties originating from North Carolina and other states. About 20 percent of the harvested acreage of SRW wheat in South Carolina is still planted to locally developed varieties.

Maryland and West Virginia planted imported varieties along with varieties developed in New York, Pennsylvania and Virginia in the early 20th Century. In 1949, varieties developed in Ohio dominated harvested acreage in both states; Ohio varieties remained important in West Virginia, while Maryland farmers shifted to varieties developed in Ohio. Both states now rely heavily on varieties originating in Indiana.

Plains States Nebraska produced SRW wheat from about 1929-39, planting varieties developed in New York and abroad. Before production of SRW wheat ceased in Kansas in 1949, varieties originating in Pennsylvania, Virginia, Kansas and abroad were harvested. The small acreage harvested in Kansas in 1979 came from varieties developed in Indiana and Missouri. Oklahoma also produced very little SRW wheat after 1949. In earlier years, varieties developed in New York, Pennsylvania, Virginia, Kansas and abroad were planted by Oklahoma farmers. Oklahoma produced a small amount of SRW wheat in 1979, most of which consisted of varieties developed in Missouri, Indiana, Arkansas, and other states.

Western States New Mexico produced SRW wheat only during the 1940s and harvested varieties developed abroad. Production ceased in Utah and Wyoming after 1929; Utah had harvested varieties developed in New York and abroad, and Wyoming used Vermont and foreign varieties. The other two states, Idaho and Montana, ceased production after 1949. Idaho planted varieties originating in New York, Washington and abroad, while Montana relied on varieties developed in New York, replacing them with Washington developed varieties by 1949.

Other Iowa ceased production of SRW wheat between 1934-49 and after 1974. Early in this century, Iowa farmers harvested varieties originating from eastern SRW producing states and from foreign sources. Later, they shifted

to varieties developed in Kansas and Wisconsin. By 1959, mostly varieties developed in Indiana were harvested.

Farmers in Washington stopped producing SRW wheat after 1964. In 1919, most of the varieties harvested in Washington were developed in New York. Washington farmers shifted primarily into locally developed varieties in 1929 and continued to plant locally developed varieties until 1959 when imported varieties became prevalent.

Summary

From 1919 to 1939, most of the SRW wheat producing states planted varieties developed in New York, Pennsylvania, Virginia, and foreign sources. Varieties developed in Ohio gained popularity in some states in the 1950s. At that time, farmers in Washington planted locally developed varieties, and varieties developed in Wisconsin were prevalent in Wisconsin and Minnesota. All of the western states ceased production of SRW wheat between 1939 and 1959. Very little SRW wheat was produced in the Plains after 1949. The planting of varieties developed in Indiana (a major producer of SRW wheat) began in the late 1950s and expanded such that they became the major varieties by 1979, except for South Carolina developed varieties being dominant in Texas and the prevalence of locally developed varieties in Wisconsin.

VARIETAL COMPOSITION OF WHEAT ACREAGE

Over the last sixty years, the number of varieties of wheat planted (to more than .1% of total wheat acreage) has increased in the major wheat producing states.[2/] The increase is most striking in HRW and HRS wheats, with

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2/ The USDA reports the percentage of total wheat acreage occupied by each variety of wheat in each state. These figures are estimated at 5-year intervals from 1919 onward. From 1919 to 1969, all varieties of wheat covering more than 0.1% of each state's total wheat acreage are reported; after 1974, varieties occupying more than 0.01% are reported.

the number of varieties of SRW wheat planted holding steady over this time-period. Further examination of the data shows that the average percentage of total wheat acreage planted to the most popular variety (hereafter referred to as the average or mean) has decreased for HRS and HRW wheats, but for SRW wheat it has increased in IL and IN and remained about the same in MO and OH. The variances show a similar pattern. These results are summarized in Table 4 for HRS, in Table 5 for HRS, and in Table 6 for SRW wheats. A discussion of these findings by type of wheat, examined at 10-year intervals from 1919 to 1979, follows.

Hard Red Winter Wheat

Turkey wheat, brought to the U.S. in the late 1880s by Russian immigrants, was almost the only variety of HRW wheat grown in the major producing states of KS, OK, TX, CO, NB and MT during the period 1919-1929. One or two other varieties of HRW were planted in very small acreages. Turkey remained dominant in CO, NB and MT through 1939. Blackhull, a selection of Turkey, was dominant in KS, OK and TX in 1939.

The average acreage share and variance of the acreage share are very high for all states due to the domination by a single variety. For example, in 1919, Turkey wheat occupied 68.6% of Oklahoma's total (or 99% of the HRW) wheat acreage, and the only other variety of HRW wheat occupied .2%[3/] This large difference results in a mean of 34.4 and a variance of 34.2 for HRW wheat.

By 1949, different varieties were dominant in all of these states, except for Pawnee in both KS and NB. The mean acreage share had fallen to about 5% from 11-41% in 1919. The variance had also fallen from 11-41 in 1919 to 4-10 in 1949. And, the number of varieties planted in these states had increased to

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3/ The remaining 31.2% of the total wheat acreage was planted to varieties other than HRW wheat, and thus, are not included in the average.

a range of 11-17.

Over the years 1949-1979, the trend of decreasing mean share and variance of the state continued. The number of varieties planted in a state continued to increase, e.g., 43 varieties were planted in KS in 1979.

Although the trend for decreasing mean share and variances occurs, a few dominant varieties, comprising more than 30% of a state's total wheat acreage, are identifiable as late as 1979. These dominant varieties were frequently developed locally or in a neighboring state, and their popularity may be attributed to their suitability for local climate and soil conditions. For example, 38.6% of total wheat acreage in NB in 1979 was planted to Centurk, a variety developed in Nebraska.

Hard Red Spring Wheat

Like the Turkey variety of HRW wheat, Marquis constituted a major proportion of the wheat acreage in the major HRS producing states of ND, SD, MN and MT for many years. Marquis was imported from Canada about 1900, and was phased out during the 1930s following an epidemic of wheat rust. Again because of the large concentration of a single variety, mean shares and variances in the HRS states were largest during 1919-1939.

In the years that followed, the number of varieties of HRS wheat planted in states increased from 4-6 in 1919 to 19-30 in 1979. Mean shares and variances decreased as the number of varieties planted increased. With the exception of MN where 61.3% of the wheat acreage was planted to Era in 1979, less than 20% of the acreage in any state was planted to a single dominant variety by 1979.

Soft Red Winter Wheat

Mean shares and variances for SRW wheat show a very different pattern than for HRW and HRS wheats over the last 60 years than for HRW and HRS wheats. The

number of varieties planted per state has remained about the same (approximately 20). Mean shares and variances have increased in IL and IN and remained about the same in the other two major producing states of MO and OH.

Unlike HRW wheat, dominated by Turkey, and HRS, dominated by Marquis, many varieties of SRW wheat were planted in the early 20th century. Approximately 24-39% of total acreage was dominated by a single variety in SRW producing states, in combination with 18 or more other varieties. The average ranged from 2% in IL to 4% in MO; variances ranged from 4.7 in IL to 7.9 in OH and MO.

This pattern remained fairly constant over the next sixty years. In 1979, the average ranged from 3.8 in OH to 5.1 in IL, with the variance ranging from 6.4 in OH to 10.0 in IL. The number of varieties planted in 1979 ranged from 17 to 26 per state and is similar to the range for 1919.

Summary

By 1979, the number of varieties planted in the major wheat producing states ranged from 20-30 per state for all 3 types of wheat. The mean shares and variances are likewise similar for all 3 wheat types, with the mean share ranging from 1.8 to 5.1%, and the variance ranging from 2.7 to 12.9. This trend is observable in almost all of the major producing states. New and competitive SRW varieties were developed earlier in the United States than for hard red winter and hard red spring wheat varieties.

BREEDING SOURCES OF WHEAT VARIETIES BY INSTITUTION

This section examines the origin of wheat varieties with regard to institution of origin, emphasizing public (USDA or state agricultural experiment station) or private developers or originators and imports. As in the other sections, USDA data are examined at 10-year intervals for 1919 to

1979. Tables 7-9 summarize the acreage planted to varieties developed by the various categories of institutional origin, for each type of wheat.

Hard Red Winter Wheat

Results for HRW wheat are summarized in Table 7. In general, the imported varieties of the early 1900s were later replaced by private and public varieties. In 1979, most varieties originated in the public sector.

In Nebraska, public varieties replaced early imported varieties. Private varieties never constituted more than 8% of the HRW acreage and more than 90% of the acreage was planted to publicly developed varieties after 1949. Colorado experienced a similar pattern of adoption. Public varieties also replaced early imports, with a peak of 23% privately developed varieties being planted. In 1959, more than 90% of the Colorado wheat acreage was planted to publicly developed varieties.

In Kansas and Texas, privately developed varieties were used extensively in the 1920s and 1930s. Privately developed varieties became popular during the 1940s, and replaced imported varieties. Later publicly developed varieties were planted. In 1949, less than 4% of wheat acreage was planted to imported varieties in both Texas and Kansas; publicly developed varieties were planted on 77% of the acreage in Kansas and 61% in Texas. Primarily publicly-developed varieties were planted in these states in 1979.

Unlike the other major HRW producing states, Oklahoma shifted directly from imports in privately-developed varieties, and privately-developed varieties remained dominant into the 1970s. From the 1940s through the 1960s, over 55% of the acreage was planted to private varieties. In 1979, private and public varieties comprised 26% and 74% of the Oklahoma wheat acreage, respectively.

Montana is also somewhat different from the other states in this group in that privately developed varieties were planted during all the 60 years of interest. The early imports were replaced later by publicly developed varieties; and the use of publicly developed varieties peaked in 1959 at 96% of the acreage. The share of the acreage planted to imports increased to 46% in 1969, then declining in subsequent years.

To summarize, all of these states relied primarily on imported varieties in 1919. Privately developed varieties first replaced imported varieties. The use of privately developed varieties peaked around 1939. Publicly developed varieties then replaced privately developed ones. In 1979, more than 90% of the acreage in Colorado and Nebraska and more than 70% of the acreage in the other major HRW wheat producing states was planted to publicly developed varieties.

Hard Red Spring Wheat

Table 8 summarizes plant breeding sources for HRS wheat. Imported varieties have been replaced mainly by publicly developed varieties. Only minor shares of privately developed HRS varieties were ever grown.

As early as 1939, North Dakota, a major HRS producer had more than 90% of the acreage planted to publicly developed varieties. This share remained high except for the 1950s, when imported varieties comprised 70% of the wheat acreage. Publicly developed varieties were planted on 94% of the North Dakota wheat acreage in 1979.

In South Dakota, use of publicly developed varieties peaked in 1949 at 97% of the acreage. In 1979, it was 64%; and 23% of the acreage was planted to private varieties. An influx of imported varieties in the 1950s caused the share of acres planted to publicly developed varieties to decline to 54% (vs.

43% imports). Before 1970, privately developed varieties constituted less than 4% of the acreage; but they accounted for 23% in 1979.

Publicly developed varieties have comprised a majority of Montana's HRS wheat acreage since 1949; their share peaked at 85.5% in 1969. Use of private varieties was negligible before 1979.

In Minnesota, publicly developed varieties of HRS wheat comprised a majority of the acreage between 1920 and 1959, when they were replaced by imports (3.9% public, 96% imports in 1959). In 1979, publicly developed varieties accounted for 95% of the acreage. Privately developed varieties never comprised more than 3.4% of the wheat acreage in Minnesota.

The major HRS wheat producing states shifted primarily between imports and publicly developed varieties. Initially, imports gave way to publicly developed varieties, a trend that reversed itself in the 1950s. As much as 96% of the Minnesota acreage of HRS wheat was planted to imports in 1959. Today, most varieties harvested are of public origins. Privately developed varieties never comprised a significant share of the acreage; the highest share was 23.2% private in South Dakota in 1979.

Soft Red Winter Wheat

Unlike HRW and HRS wheats, SRW wheat acreage was not dominated by imported varieties in the early 1900s. Privately-developed varieties (and varieties of unknown origin) comprised most of the early U.S. SRW wheat acreage. Later, publicly developed varieties replaced private ones (see Table 9).

Missouri, the major producer of SRW wheat, had 63% of its SRW wheat acreage planted to privately developed varieties as early as 1919. This proportion peaked at 82.4% in 1949. Publicly developed varieties gradually replaced the private varieties, and by 1969, 99.6% were publicly developed ones.

Ohio's proportion of private varieties peaked at 30.4% in 1919, but a large share was of unknown origin. Publicly developed varieties became dominant by 1929, which was very early compared to other states, and they comprised 75% of the SRW acreage. The Ohio Agricultural Experiment Station's early role in testing wheat varieties may have been a factor. By 1969, 100% of the SRW wheat varieties grown in Ohio were developed publicly.

In Illinois, privately developed varieties accounted for 67% of the acreage in 1919. This share decreased to 32% in 1949 and to .5% in 1959. Later, these private varieties were replaced by publicly developed varieties.

Indiana producers of SRW wheat planted approximately half of their crop to privately developed varieties during 1919-1939. More than 40% was planted to varieties of unknown origin, but private varieties had largely ceased to be planted in 1959. In 1969, all of the SRW wheat acreage was planted to public varieties.

In the early years of the 20th Century, most varieties of SRW wheat that were grown were of private (or unknown) origin. Some imported and almost no publicly developed varieties were planted at that time. After 1949, less than 1% unknown or imported varieties were harvested. Publicly developed varieties gained steadily; and by 1959, they accounted for more than 90% of the SRW wheat acreage in these four states. In 1969, publicly developed varieties covered 100% of the acreage in Illinois, Indiana, and Ohio, and 99.6% in Missouri. A small amount of privately developed wheat varieties has come into use in the last 15 years, but was still less than 10% of the acreage in 1979.

Summary

In the 1920s, large shares of the HRW and HRS wheat acreage were planted to imported varieties, e.g., Turkey (HRW) and Marquis (HRS). SRW wheat

acreage, which had been grown in the U.S. for a much longer time, was planted mainly to varieties that were privately developed or of unknown origin. As the role of the state agricultural experiment stations grew in the 1930s and 1940s, publicly developed varieties became prominent for all three types of wheat in all of the major producing states. Use of privately developed varieties peaked in 1939 for HRW wheat, and declined steadily after 1919 for SRW wheat. Privately developed varieties were not in widespread use for HRW, as imported varieties were replaced by public varieties.

Publicly developed varieties replaced early imports for the three types of wheat considered here, except HRS wheat. In the 1950s, imports were dominant. However, they too, were later replaced by publicly developed varieties. For the SRW wheats, more than 90% acreage were publicly developed varieties by 1959, and their use rose to 100% in 1969. More than 70% of the HRW wheat acreage was planted to publicly developed varieties in 1979.

Conclusion

Methods of wheat improvement changed as scientific investigation shed light on applications of genetic research. Before 1900, varieties were developed by chance or with little understanding of the principles of genetics. Today, scientific methods are employed to meet specific needs of wheat producers and consumers.

Soft red winter wheat is best suited for the east coast climate. Hard red winter and hard red spring wheats are adapted to the Midwest and western United States. It is not surprising then, considering the westward development of the U.S., that American varieties of SRW wheat were developed earlier than HRS and HRW wheat varieties. Also, private sources were important for SRW wheat in the late 1800s and early 1900s, before agricultural experiment stations moved beyond varietal testing into plant breeding. The heavy reliance on a few

foreign varieties of HRS and HRW wheats subsided as many varieties were adopted, most of which were developed by public agencies.

The pattern of wheat varietal adoption changed over the period 1919-1979. Geographical sources have moved, for the most part, to the major wheat producing states. Institutional sources have evolved from an early dependence on foreign imports to public agencies as the role of experiment stations grew. Dependence on a single variety by many producers has decreased as the number of HRW and HRS varieties available has increased.

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Table 1. The Plant Breeding Source of Hard Red Winter Wheat Varieties Harvested by State 1919-1979

State	Year	Total wheat acreage harvested (1000 ac)	Percent hard red winter wheat	Hard red winter wheat harvested (1000 ac)	Origin of varieties harvested: Home state %	Touching states %	Foreign imports %	Other states %
A. Major hard red winter producing states								
1. Kansas	1919	11,280	83.2	9,385	1.0	-	99.0	-
	24	9,717	91.1	8,852	32.4	-	67.6	-
	29	12,081	94.3	11,392	48.9	-	50.9	0.2
	34	13,004	92.2	11,990	51.2	-	48.4	0.4
	39	13,895	90.4	12,561	66.6	0.2	32.0	1.2
	44	13,103	97.8	12,815	83.2	1.1	15.0	0.7
	49	16,244	98.0	15,919	72.4	25.5	1.7	0.4
	54	11,738	99.3	11,657	76.2	23.1	0.3	0.4
	59	10,870	99.7	10,837	74.7	24.4	0.3	0.6
	64	10,641	99.6	10,598	68.4	30.0	-	1.6
	69	10,767	99.4	10,702	31.6	66.1	-	2.3
	74	12,000	99.2	11,904	37.7	59.8	-	2.5
	79	12,100	99.1	11,991	46.1	46.4	-	7.5
2. Oklahoma	1919	4,718	68.8	3,246	-	0.3	99.7	-
	24	3,509	84.0	2,948	-	37.7	62.3	-
	29	4,576	89.8	4,109	0.2	46.9	52.9	-
	34	3,541	84.4	3,989	1.4	45.1	53.4	0.1
	39	4,851	89.3	4,332	2.9	60.1	36.2	0.8
	44	5,206	95.3	4,961	1.5	78.4	15.7	4.4
	49	7,552	99.1	7,484	41.9	44.8	1.6	11.7
	54	5,294	99.1	5,246	41.0	55.2	0.6	3.2
	59	5,034	99.5	5,009	67.8	2.0 ?	0.3	?
	64	4,882	98.9	4,828	69.6	30.0	0.1	0.3
	69	5,299	99.7	5,283	63.1	22.0	-	14.9
	74	7,000	97.7	6,839	52.4	23.5	-	24.1
	79	7,000	97.9	6,839	33.7	49.7	-	16.6
3. Texas	1919	2,401	33.9	814	-	-	100.0	-
	24	1,312	74.9	983	-	-	96.3	3.7
	29	2,970	84.4	2,507	-	-	63.7	36.3
	34	4,087	90.8	3,711	-	-	70.8	29.2
	39	3,919	92.1	3,609	-	-	24.6	75.4
	44	4,450	93.6	4,165	-	-	59.1	40.9
	49	7,697	93.0	7,158	25.0	18.5	29.5	24.0
	54	4,840	95.4	4,617	22.4	18.0	31.4	28.2
	59	4,287	94.1	4,034	18.9	47.1	0.4	33.6
	64	4,002	95.0	3,802	23.3	51.2	-	25.5
	69	4,124	88.4	3,646	38.1	39.9	-	22.0
	74	5,600	89.1	4,990	44.8	25.3	-	29.9
	79	5,800	85.0	4,930	44.1	25.9	-	30.0
4. Colorado	1919	1,329	67.0	890	-	-	100.0	-
	24	1,306	74.8	977	-	31.8	68.2	-
	29	1,539	71.9	1,107	-	28.4	72.6	-
	34	1,555	74.7	1,162	-	28.4	71.6	-
	39	1,663	79.1	1,315	-	44.1	55.9	-
	44	1,608	88.4	1,421	-	69.7	30.3	-
	49	3,622	90.4	3,274	-	89.9	10.0	0.17
	54	3,076	97.1	2,987	-	96.5	3.4	0.15
	59	2,842	98.9	2,811	-	97.7	1.9	0.40
	64	2,782	99.3	2,763	-	98.2	0.6	1.20
	69	3,115	98.8	3,078	-	97.9	1.1	1.01
	74	2,836	97.7	2,771	0.6	97.3	0.2	1.14
	79	3,245	97.3	3,157	22.8	75.6	-	1.44

Table 1. Continued

State	Year	Total wheat acreage harvested (1000 ac)	Percent hard red winter wheat	Hard red winter wheat harvested (1000 ac)	Origin of varieties harvested			
					Home state %	Touching states %	Foreign imports %	Other states %
5. Nebraska	1919	4,230	82.9	3,507	-	-	100.0	-
	24	3,007	90.6	2,724	0.8	28.9	70.1	0.2
	29	3,700	91.5	3,386	10.1	15.4	74.5	-
	34	3,331	89.6	2,985	22.4	11.2	66.4	-
	39	3,987	94.2	3,756	26.7	11.2	61.6	0.5
	44	3,705	96.7	3,583	44.4	10.6	44.9	0.1
	49	4,686	98.4	4,611	69.8	22.5	7.9	-
	54	3,745	98.6	3,693	74.6	22.2	2.7	0.5
	59	3,444	98.9	3,406	70.7	27.7	1.0	0.6
	64	3,235	98.2	3,177	62.9	35.6	0.1	1.4
	69	2,999	98.5	2,954	94.0	5.5	0.1	0.4
	74	3,000	99.4	2,982	97.7	2.3	0.1	-
	79	3,000	100.0	3,000	94.1	5.0	1.8	3.6
6. Montana	1919	1,710	21.7	371			100.0	-
	24	3,103	19.8	614	3.5		96.0	.50
	29	4,419	15.5	685	16.5		81.3	2.2
	34	3,523	20.0	705	17.0		80.5	2.5
	39	4,041	21.6	873	19.7		75.5	4.8
	44	4,313	28.5	1,229	24.7		66.3	9.0
	49	5,906	27.8	1,642	51.3		25.2	23.5
	54	4,710	31.3	1,474	52.7	.20	11.8	35.3
	59	4,391	43.3	1,901	25.9		4.2	69.9
	64	4,004	48.7	1,950	8.9		1.9	89.2
	69	3,809	64.4	2,453	2.3	.20	46.0	51.5
	74	5,020	53.4	2,681	3.7	7.0	40.0	49.3
	79	5,985	47.2	2,825	1.3	8.4	25.5	64.8

Table 2. The Plant Breeding Source of Hard Red Spring Wheat Varieties Harvested by State 1919-1979

State	Year	Total wheat acreage harvested (1000 ac)	Percent hard red spring wheat	Hard red spring wheat harvested (1000 ac)	Origin of varieties harvested: Home state %	Touching states %	Foreign imports %	Other states %
A. Major hard red spring producing states								
1. North Dakota	1919	9,098	69.40	6,314	.1	11.7	88.2	-
	24	8,323	66.60	5,543	8.3	.9	90.8	-
	29	9,969	59.80	5,962	6.7	.8	92.3	.2
	34	8,757	77.40	6,778	44.7	.4	54.7	.2
	39	8,378	68.70	5,756	29.6	61.6	8.7	.1
	44	10,162	82.00	8,333	48.4	32.2	19.4	-
	49	10,942	72.10	7,889	67.3	24.9	7.5	.3
	54	8,239	81.10	6,682	25.6	67.5	6.3	.6
	59	6,751	84.50	5,705	9.4	20.7	69.8	.1
	64	6,417	64.30	4,126	43.6	19.7	36.7	-
	69	6,938	55.60	3,858	35.1	38.3	23.4	3.2
	74	10,210	63.42	6,475	62.0	13.3	2.8	21.9
	79	9,900	62.37	6,175	82.4	11.0	.1	6.5
2. Montana	1919	1,710	50.90	870	-	-	88.0	12.0
	24	3,103	74.10	2,299	-	.3	78.9	20.8
	29	4,419	81.20	3,588	-	.6	99.0	.4
	34	3,523	77.20	2,720	-	5.9	93.9	.2
	39	4,041	76.70	3,099	-	20.9	76.3	2.8
	44	4,313	69.90	3,015	-	23.3	44.4	32.3
	49	5,906	70.70	4,176	.2	26.5	36.6	36.7
	54	4,710	66.40	3,127	.2	23.6	24.0	52.2
	59	4,391	53.50	2,349	12.2	13.3	36.3	38.2
	64	4,004	42.40	1,698	9.0	12.7	34.0	44.3
	69	3,809	26.90	1,025	3.7	57.6	14.0	24.7
	74	5,020	39.53	1,984	1.5	57.6	15.4	25.5
	79	5,985	43.41	2,598	15.7	55.3	5.3	23.7
3. Minnesota	1919	3,793	90.20	3,421	11.1	-	88.9	-
	24	1,644	84.40	1,388	3.1	1.2	95.7	-
	29	1,315	69.20	910	1.9	2.4	95.7	-
	34	1,644	80.40	1,322	10.8	27.5	61.7	-
	39	1,609	85.20	1,371	92.4	4.7	2.9	-
	44	1,329	83.50	1,110	21.6	46.1	32.3	-
	49	1,300	86.80	1,128	5.3	77.8	15.8	1.1
	54	735	9,090	668	74.8	23.0	1.9	.3
	59	1,018	94.90	966	.7	3.3	96.0	-
	64	941	84.80	798	1.5	26.4	72.1	-
	69	852	88.30	752	69.9	1.3	25.5	3.3
	74	2,860	94.20	2,694	71.7	4.4	.9	23.0
	79	2,640	94.78	2,502	74.0	14.6	.2	11.2
4. South Dakota	1919	3,895	72.80	2,836	-	-	99.5	.5
	24	2,364	52.30	1,236	-	2.9	96.2	.9
	29	3,539	55.30	1,957	.4	8.9	89.5	1.2
	34	3,263	72.50	2,366	.1	35.9	63.9	.1
	39	3,006	71.20	2,140	.6	83.0	16.4	-
	44	3,255	84.60	2,754	.6	90.4	9.0	-
	49	4,368	84.50	3,691	.6	95.5	3.7	.2
	54	2,806	81.30	2,281	47.6	50.4	1.6	.4
	59	2,686	74.20	1,993	17.9	39.2	42.6	.3
	64	2,261	62.80	1,420	11.8	49.2	39.0	-
	69	2,184	50.90	1,112	2.0	78.8	14.7	4.5
	74	3,305	60.20	1,990	.03	61.6	.7	37.6
	79	3,455	55.48	1,917	2.5	73.7	2.1	21.7

Table 3. The Plant Breeding Source of Soft Red Winter Wheat Varieties Harvested by State 1919-1979

State	Year	Total wheat acreage harvested (1000 ac)	Percent soft red winter wheat	Soft red winter wheat harvested (1000 ac)	Origin of varieties harvested: Home state %	Touching states %	Foreign imports %	Other states %
A. Major soft red winter producing states								
1. Missouri	1919	4,564	75.5	3,446			37.0	63.0
	24	1,439	84.3	1,213			34.8	65.2
	29	1,534	84.1	1,290			39.8	60.2
	34	1,643	90.8	1,492			49.9	50.1
	39	1,886	80.9	1,526	3.1	23.4	31.8	41.7
	44	1,714	90.5	1,551	2.0	52.0	13.0	33.0
	49	2,125	51.8	1,101	.20	77.0	4.8	18.0
	54	1,481	43.1	638	4.9	17.9	.70	76.5
	59	1,705	32.4	552	1.9	3.7		94.4
	64	1,621	41.7	676	.20	.20		99.6
	69	1,190	51.0	607	9.2	-		90.8
	74	1,450	77.3	1,121	1.2	-		98.8
	79	1,780	87.2	1,552	.40	1.8		97.8
2. Ohio	1919	2,923	76.2	2,227	5.1	14.2	66.7	14.0
	24	1,819	92.2	1,677	52.5	3.9	36.7	6.9
	29	1,564	93.5	1,462	76.3	1.8	17.4	4.5
	34	1,994	92.8	1,850	76.9	1.8	16.7	4.6
	39	2,038	90.6	1,846	86.1	1.3	9.1	3.5
	44	2,058	94.5	1,945	90.3	.90	5.7	3.1
	49	2,377	93.8	2,230	85.7	6.9	5.9	1.5
	54	1,783	95.1	1,696	82.2	13.7	2.7	1.4
	59	1,578	97.3	1,535	67.0	17.7		15.3
	64	1,417	98.6	1,397	27.2	62.9		9.9
	69	1,105	98.2	1,085	7.7	89.7		2.6
	74	1,580	98.2	1,552	16.3	82.7		1.0
	79	1,350	97.5	1,316	38.7	56.6		4.7
3. Illinois	1919	4,105	54.3	2,229	.80	.40	34.3	64.5
	24	2,250	45.0	1,013	.20	.20	24.9	74.7
	29	2,093	46.5	973	.20	.20	26.6	73.0
	34	2,080	55.6	1,157	.20	.20	19.0	80.6
	39	1,951	55.1	1,075	.40	.40	9.8	89.4
	44	1,347	76.3	1,028	1.4	1.4	16.9	80.3
	49	2,057	57.2	1,177	14.5	14.5	7.1	63.9
	54	1,580	34.0	537	34.4	34.4	1.5	29.7
	59	1,777	41.2	732	1.5	30.6	-	67.9
	64	1,852	40.4	748	-	84.4	-	15.6
	69	1,359	56.9	773	-	93.7	-	6.3
	74	1,850	79.0	1,462	-	94.6	-	5.4
	79	1,360	87.0	1,183	.10	97.1	-	2.8
4. Indiana	1919	2,799	84.1	2,354	.50	12.3	42.6	44.6
	24	1,605	81.9	1,315	.20	17.6	36.3	45.9
	29	1,533	72.2	1,107	.10	19.2	25.1	55.6
	34	1,845	77.3	1,426	.30	21.2	20.3	58.2
	39	1,627	79.1	1,287	4.2	30.3	16.7	48.8
	44	1,338	81.5	1,091	9.7	36.6	8.1	45.6
	49	1,775	90.6	1,608	55.2	32.6	3.8	8.4
	54	1,315	92.5	1,216	62.4	34.8	1.2	1.6
	59	1,361	97.0	1,320	49.4	9.2	-	41.4
	64	1,476	98.7	1,457	84.5	1.1	-	14.4
	69	956	96.3	921	91.3	-	-	8.7
	74	1,440	98.8	1,423	98.8	.30	-	.90
	79	1,000	97.0	970	88.9	2.2	-	8.9

Table 4. HRW

		1919	1929	1939	1949	1959	1969	1979
Kansas								
No. of varieties		3	5	9	15	16	25	43
Range	Low	.1	.2	.2	.1	.2	.1	.01
	High	82.3 (Turkey)	48.0 (Turkey)	31.0 (Blackhull)	36.0 (Pawnee)	22.7 (Wichita)	42.2 (Scout)	21.0 (Eagle)
$\bar{X}$		27.73	18.86	10.04	6.53	6.23	3.97	2.3
σ		38.59	18.90	12.04	9.47	6.84	8.14	4.43
Oklahoma								
No. of varieties		2	7	13	17	19	19	33
Range	Low	.2	.1	.1	.1	.1	.1	.01
	High	68.6 (Turkey)	47.4 (Turkey)	36.6 (Blackhull)	41.5 (Triumph)	59.0 (Triumph)	31.2 (ImpTriumph)	35.9 (TamW101)
$\bar{X}$		34.4	12.87	6.87	5.83	5.24	5.25	2.97
σ		34.2	18.29	11.47	10.1	13.55	8.0	6.47
Texas								
No. of varieties		1	3	6	16	21	27	36
Range	Low	0	13.2	.4	.1	.1	.1	.01
	High	33.9 (Turkey)	51.4 (Turkey)	40.8 (Blackhull)	26.0 (Westar)	30.3 (Triumph)	13.6 (ImpTriumph)	11.1 (TamW101)
$\bar{X}$			28.13	15.35	5.81	4.48	3.27	2.36
σ			16.67	17.1	7.11	7.35	4.26	2.99
Colorado								
No. of varieties		2	5	6	16	17	20	26
Range	Low	.5	.1	.9	.1	.1	.1	.02
	High	66.5 (Turkey)	51.4 (Turkey)	44.2 (Turkey)	19.2 (Comanche)	64.5 (Wichita)	34.8 (Scout)	23.6 (Scout 66)
$\bar{X}$		33.5	14.38	13.18	5.65	5.82	4.94	3.74
σ		33.0	19.59	15.2	5.78	14.98	9.73	6.72
Nebraska								
No. of varieties		2	5	11	16	14	21	32
Range	Low	.2	.3	.1	.1	.1	.1	.01
	High	82.7 (Turkey)	68.2 (Turkey)	58.0 (Turkey)	33.4 (Pawnee)	31.0 (Pawnee)	32.0 (Lancer)	38.6 (Centurk)
$\bar{X}$		41.45	18.3	8.56	6.15	7.06	4.69	3.13
σ		41.25	25.45	16.31	6.25	11.3	8.83	7.28
Montana								
No. of varieties		2	6	6	11	13	16	20
Range	Low	.1	.1	.2	.1	.1	.1	.01
	High	21.6 (Turkey)	12.5 (Turkey)	16.3 (Turkey)	9.4 (Yogo)	17.8 (Cheyenne)	29.4 (Winalta)	14.6 (Centurk)
$\bar{X}$		10.85	2.58	3.6	2.53	3.33	4.03	2.86
σ		10.75	4.47	5.74	3.59	5.39	8.58	4.37

Table 5. HRS

	1919	1929	1939	1949	1959	1969	1979
North Dakota							
No. of varieties	6	11	12	18	18	21	19
Range Low	.1	.1	.1	.1	.1	.1	.02
Range High	47.0 (Marquis)	52.6 (Marquis)	41.6 (Thatcher)	31.9 (Mida)	57.1 (Selkirk)	17.4 (Chris)	18.6 (Olaf)
$\bar{X}$	11.57	5.44	5.73	4.01	4.69	2.65	3.29
σ	16.2	14.94	12.12	7.69	13.08	4.64	5.57
Montana							
No. of varieties	4	11	6	17	14	16	21
Range Low	1.3	.1	.1	.1	.1	.1	.01
Range High	40.3 (Marquis)	72.8 (Marquis)	55.6 (Marquis)	24.9 (Thatcher)	18.0 (Thatcher)	14.5 (Fortuna)	10.7 (Fortuna)
$\bar{X}$	12.73	7.38	12.78	4.16	3.82	1.68	2.07
σ	16.01	20.77	19.91	7.13	4.97	3.57	2.66
Minnesota							
No. of varieties	5	9	12	16	8	12	21
Range Low	.5	.1	.1	.1	.1	.1	.02
Range High	57.3 (Marquis)	59.3 (Marquis)	71.6 (Thatcher)	32.7 (Mida)	91.1 (Selkirk)	50.4 (Chris)	61.3 (Era)
σ							
$\bar{X}$	18.04	7.69	7.10	5.43	11.86	7.36	4.51
	20.97	18.29	19.55	9.58	29.96	14.09	12.87
South Dakota							
No. of varieties	4	10	11	15	13	17	30
Range Low	.4	.1	.1	.2	.1	.1	.03
Range High	61.2 (Marquis)	47.1 (Marquis)	33.5 (Ceres)	35.1 (Mida)	31.0 (Selkirk)	14.0 (Chris)	12.6 (Olaf)
$\bar{X}$	18.2	5.53	6.46	5.63	5.71	2.99	1.85
σ	25.14	13.91	11.05	11.36	9.55	3.69	2.97

Table 6. SRW

	1919	1929	1939	1949	1959	1969	1979
Missouri							
No. of varieties	19	15	18	19	15	16	20
Range Low	.1	.1	.1	.1	.1	.1	.05
Range High	35.2 (Fultz)	24.6 (Fultz)	17.3 (Red May)	35.8 (Clarkan)	14.6 (Knox)	30.4 (Monon)	36.29 (Arthur71)
$\bar{X}$	3.97	5.61	4.49	2.73	2.16	3.19	4.36
σ	7.86	7.49	5.52	7.86	4.16	7.42	8.71
Ohio							
No. of varieties	24	19	20	20	21	21	26
Range Low	.1	.1	.1	.1	.1	.1	.01
Range High	38.8 (Poole)	53.6 (Trumbull)	54.0 (Trumbull)	63.3 (Thorne)	48.9 (Seneca)	49.2 (Monon)	21.2 (Arthur)
$\bar{X}$	3.18	4.92	4.53	4.69	4.63	4.68	3.75
σ	7.85	11.86	12.17	13.63	10.52	10.83	6.35
Illinois							
No. of varieties	26	19	20	23	13	9	17
Range Low	.1	.1	.1	.1	.1	.1	.06
Range High	24.2 (Fultz)	19.8 (Fultz)	18.8 (Fulhio)	12.8 (Thorne)	23.0 (Knox)	37.6 (Monon)	35.6 (Arthur71)
$\bar{X}$	2.06	2.45	2.76	2.49	3.17	6.32	5.12
σ	4.69	4.49	5.50	2.92	6.13	11.78	9.99
Indiana							
No. of varieties	24	22	17	19	13	12	23
Range Low	.1	.1	.1	.1	.1	.1	.06
Range High	25.3 (Poole)	17.2 (Fultz)	21.0 (Fultz)	29.2 (Fairfield)	38.6 (Knox)	55.1 (Monon)	28.9 (Arthur71)
$\bar{X}$	3.42	3.28	4.65	4.77	7.46	8.03	4.22
σ	6.05	5.15	5.87	8.17	11.87	14.80	7.49

Table 7. HRW Wheat

State	Year	% PV	% PB	% Unk	% IM
Montana	1919	-	-	-	100.0
	1929	-	18.8	-	81.2
	1939	-	24.5	-	75.5
	1949	-	74.9	-	25.1
	1959	-	95.8	-	4.2
	1969	-	54.0	-	46.0
	1979	-	74.6	-	25.4
Kansas	1919	-	1.0	-	99.0
	1929	35.7	13.0	-	51.3
	1939	39.5	28.3	-	32.2
	1949	20.9	77.3	-	1.7
	1959	25.3	73.1	1.3	.3
	1969	16.1	73.8	10.1	-
	1979	10.7	88.6	0.5	0.2
Texas	1919	-	-	-	100.0
	1929	15.6	23.5	-	60.9
	1939	45.3	13.8	-	40.9
	1949	37.1	61.4	-	1.5
	1959	34.1	63.3	2.1	.4
	1969	31.1	65.6	3.3	-
	1979	19.1	80.8	-	0.1
Colorado	1919	-	-	-	100.0
	1929	2.5	25.5	-	72.0
	1939	11.5	32.6	-	55.9
	1949	23.2	66.7	-	10.0
	1959	2.9	94.3	.8	1.9
	1969	.3	97.5	1.1	1.1
	1979	.3	99.4	.3	-
Nebraska	1919	-	-	-	100.0
	1929	.6	24.6	-	74.8
	1939	6.7	31.7	-	61.6
	1949	2.2	89.8	-	8.0
	1959	7.8	90.9	0.3	1.0
	1969	.6	99.2	.1	.1
	1979	.2	99.6	-	.2
Oklahoma	1919	-	.3	-	99.7
	1929	38.5	8.4	-	53.1
	1939	47.4	16.5	-	36.2
	1949	56.1	42.3	-	1.6
	1959	59.9	39.5	.3	.3
	1969	59.6	31.1	9.3	-
	1979	25.9	73.9	0.2	-

Table 8. HRS Wheat

State	Year	% PV	% PB	% Unk	% IM
N. Dakota	1919	.3	11.5	–	88.2
	1929	.8	6.9	–	92.3
	1939	1.9	90.8	–	7.3
	1949	–	92.6	–	7.4
	1959	0.3	29.9	0.1	69.7
	1969	1.8	74.8	–	23.4
	1979	6.1	93.6	–	0.3
S. Dakota	1919	–	5.2	–	94.8
	1929	.2	10.3	–	89.5
	1939	.6	82.9	–	16.5
	1949	.4	96.7	–	3.0
	1959	3.6	53.8	–	42.6
	1969	3.7	81.5	–	14.7
	1979	23.2	64.4	0.2	12.2
Montana	1919	–	12.0	–	88.0
	1929	.2	.7	–	99.0
	1939	–	23.7	–	76.3
	1949	–	63.9	–	36.1
	1959	.4	63.4	–	36.3
	1969	0.3	85.5	–	14.1
	1979	17.9	79.3	–	2.8
Minnesota	1919	.6	10.5	–	88.9
	1929	.1	4.2	–	95.7
	1939	.1	96.9	–	2.9
	1949	–	84.3	–	15.7
	1959	.1	3.9	–	96.0
	1969	0.1	73.5	–	26.3
	1979	3.4	94.9	0.1	1.6

Table 9. SRW Wheat

State	Year	% PV	% PB	% Unk	% IM
Illinois	1919	66.9	.2	19.6	13.4
	1929	66.6	8.2	19.6	5.6
	1939	53.2	37.7	7.4	1.8
	1949	31.8	61.4	1.9	4.9
	1959	.5	99.5	-	-
	1969	-	100.0	-	-
	1979	1.0	99.0	-	-
Indiana	1919	52.8	.5	41.1	5.5
	1929	51.1	5.0	42.4	1.5
	1939	51.5	18.0	30.5	.1
	1949	15.8	80.6	3.1	.6
	1959	.5	99.5	-	-
	1969	-	100.0	-	-
	1979	7.1	92.1	0.7	0.1
Missouri	1919	63.2	.1	26.1	10.6
	1929	60.2	-	36.5	3.2
	1939	44.6	23.6	30.0	1.7
	1949	82.4	12.7	.6	4.2
	1959	9.1	90.5	.3	-
	1969	.4	99.6	-	-
	1979	6.3	93.7	-	-
Ohio	1919	30.4	6.2	59.3	4.1
	1929	11.2	74.9	13.2	.8
	1939	8.2	84.4	7.2	.2
	1949	2.7	93.4	3.2	.7
	1959	1.0	98.7	.3	-
	1969	-	100.0	-	-
	1979	4.3	95.7	-	-